

DOE/OE Transmission Reliability Program

PMU Error Impact on Measurement-Based Applications

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Objective and Accomplishments

- **Overall Project Objective**

Assess the impact of the measurement errors on synchrophasor based applications

- **Looking Back (July 2014 - June 2015)**

- Completed error impact study for four (4) applications
- Three (3) Related Best Papers at 2015 PES General Meeting

J. Zhao, L. Zhan, Y. Liu, H. Qi, J. R. Garcia, and P. D. Ewing, “Measurement accuracy limitation analysis on synchrophasors”, IEEE PESGM 2015. (This study performed in 2014)

L. Zhan, J. Zhao, S. Gao, J. Culliss, Y. Liu, and Y. Liu, “Universal grid analyzer design and development”, IEEE PESGM 2015 (related work).

H. Lu, L. Zhan, Y. Liu, and W. Gao, “A GPS-free power grid monitoring system over mobile platforms”, IEEE PESGM 2015 (related work).



FY15 Accomplishments and Deliverables

- **Effect of renewable sources on measurement accuracy**
 - Study impact of wind turbine blade shadow effect (Mar 2015)
 - Study impact of harmonics from PV inverters (July 2015)
- **GPS loss statistics and impacts**
 - GPS loss rate from historical PMU and FDR data (Aug 2015)
 - Impact of GPS loss on time drift and measurement error (Aug 2015)
 - GPS loss distribution in relation to time and location (Oct 2015)



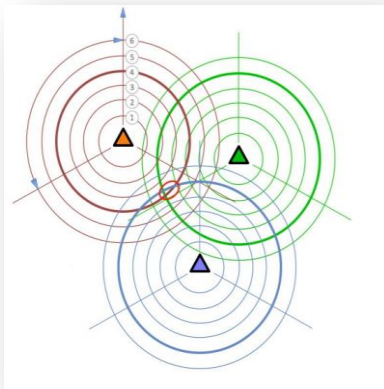
Risks and Thoughts for Future

- **Risks or uncertainties** - No known risks or uncertainties
- **Early thoughts on follow-on work**
 - Impact of communication delay (FY16)
 - Impact of data loss (FY16)
 - Evaluate the benefit of increased data reporting rate (FY17)
 - Re-visit the distribution level measurement accuracy limits (FY17)

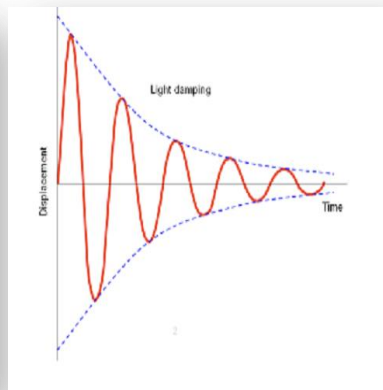


Selected Applications

- PMU applications for this study



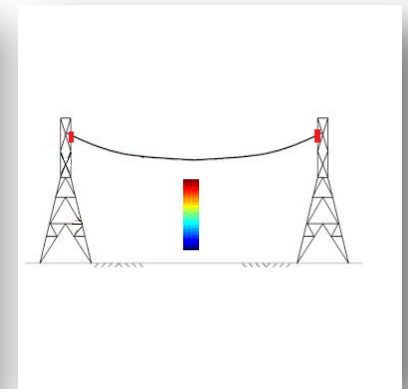
**Event
Location**



**Oscillation
Detection**



**Islanding
Detection**



**Dynamic
Line Rating**



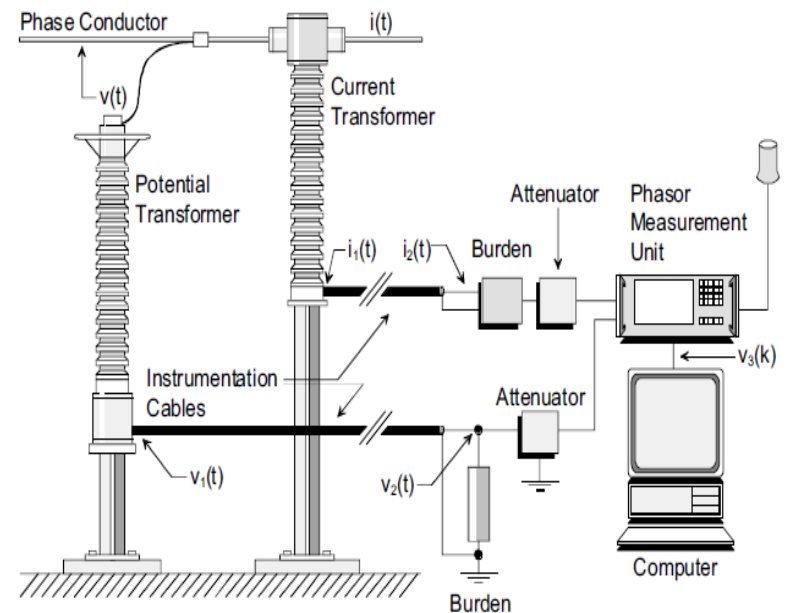
Error Sources Used in the Study

- **PMU Error**

- IEEE Std C37.118.1-2011, C37.118.1a-2014
- Phase angle: 0.57° (0.6°) based on 1% TVE
- Frequency error: 0.005 Hz

- **Instrument Channel Error**

- PT, CT, CCVT, Cable combined error
- -0.2° to -1.0° for most cases*



*A. P. Meliopoulos, et al. , *Synchrophasor Measurement Accuracy Characterization*, NASPI Performance & Standards Task Team, 2007, pp. 43-58.



Methodology

- **Assumption**

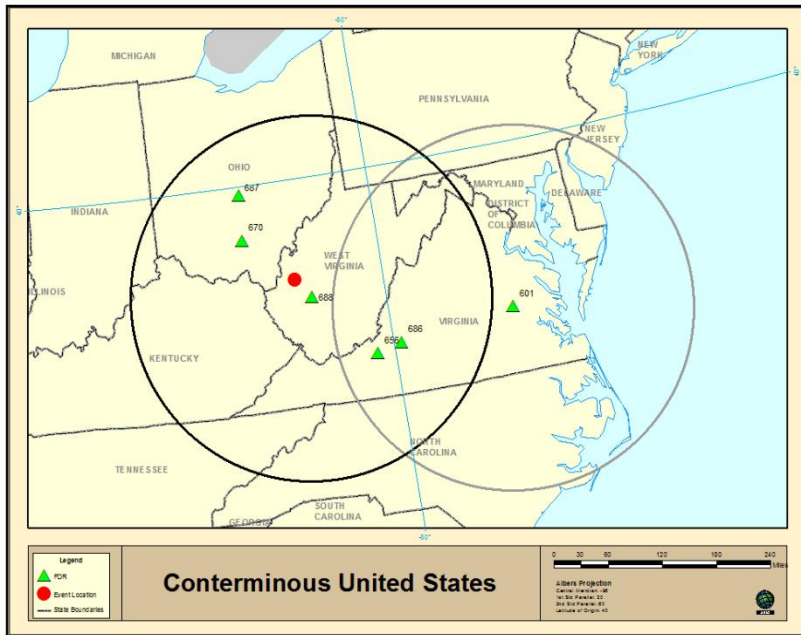
- Frequency error: ± 0.005 Hz (most PMUs are better)
- Angle error
 - PMU part : $\pm 0.6^\circ$ (most units are better)
 - Instrumentation channels -1.0° (maximum)
This number varies with installation situation and impacts only applications using absolute angles.

- **Approach**

- Assume the maximum error
- Find the worst case



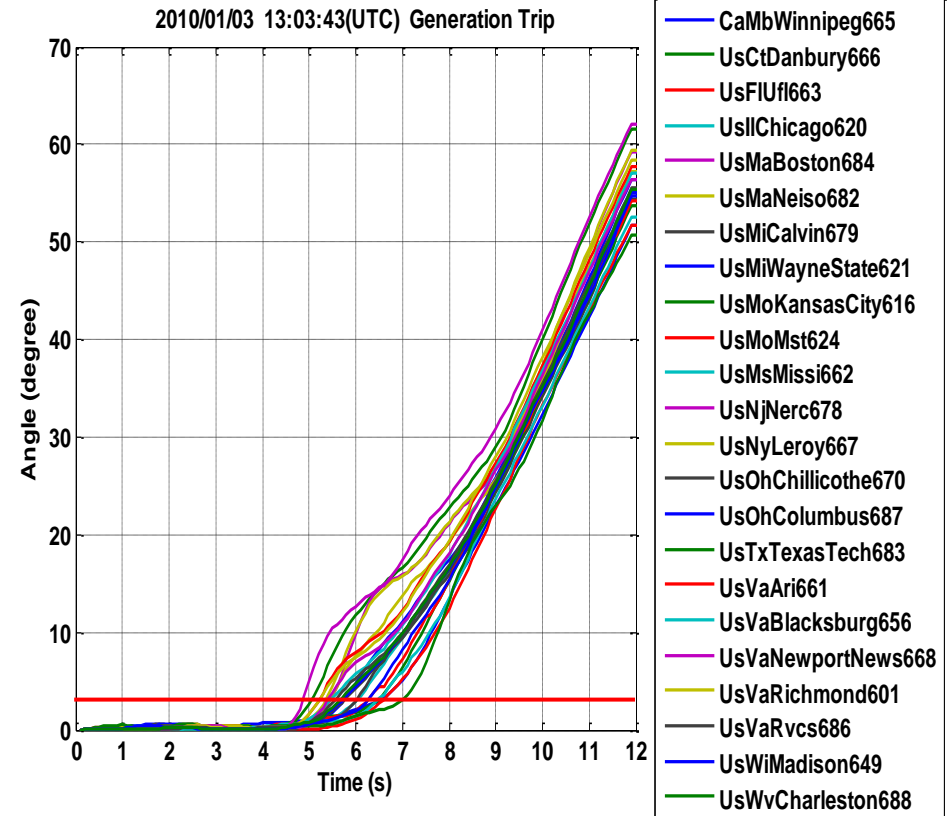
Angle-Based Event Location



▲ : first responding FDR

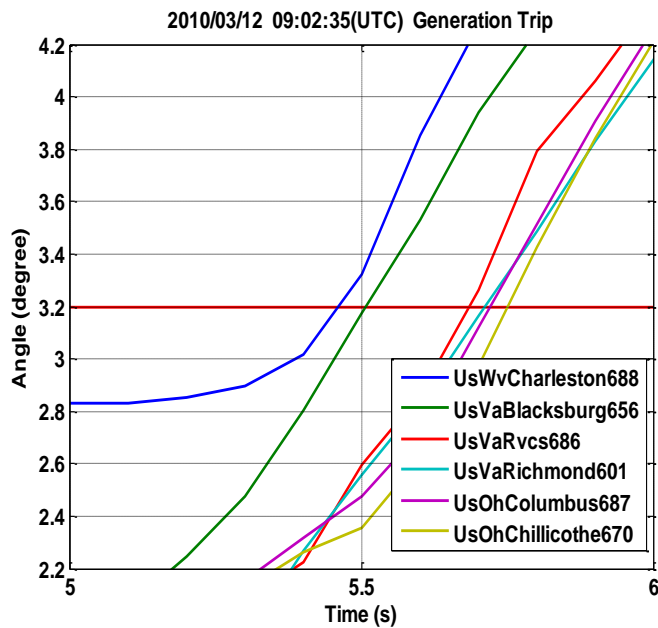
○ : event location range

● : possible power plants

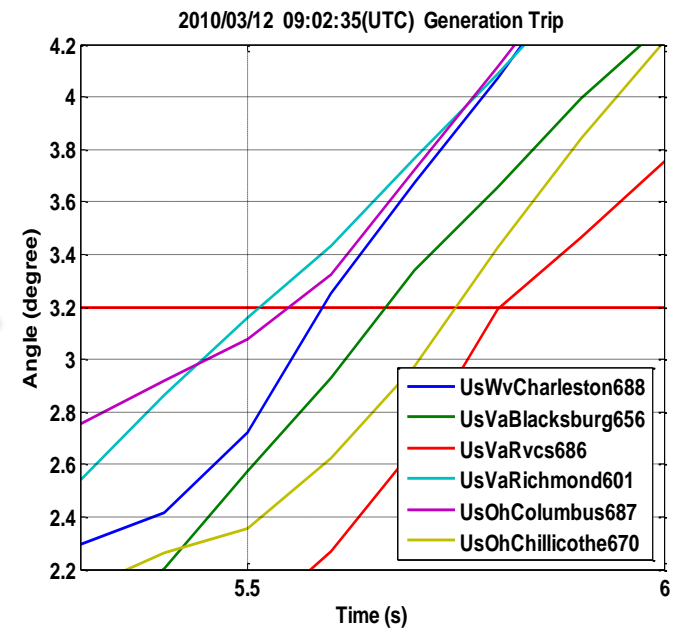


How Error Impact the detection order

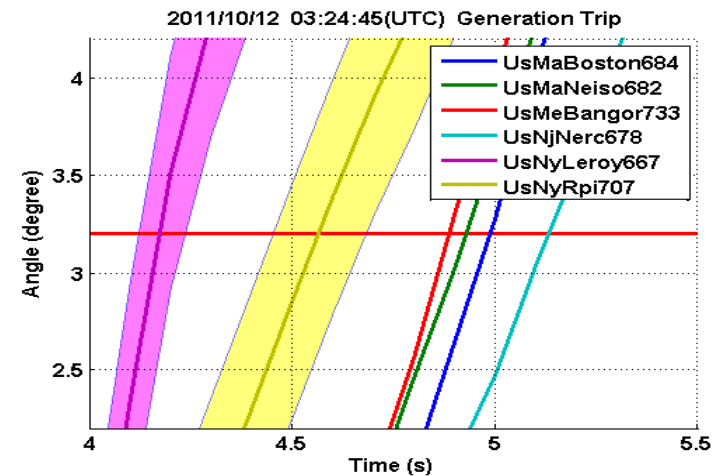
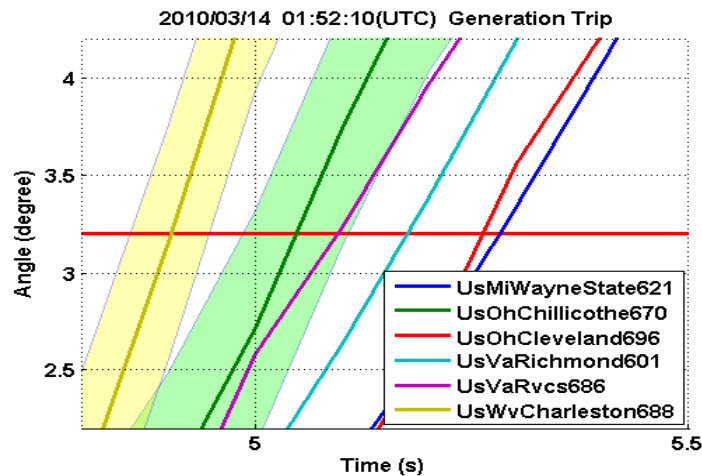
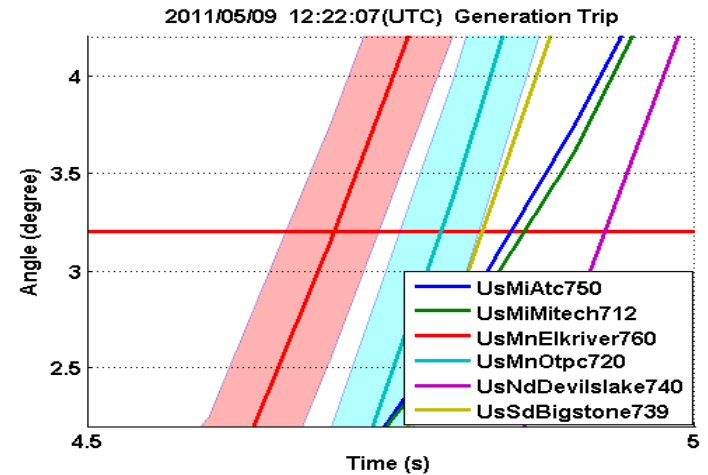
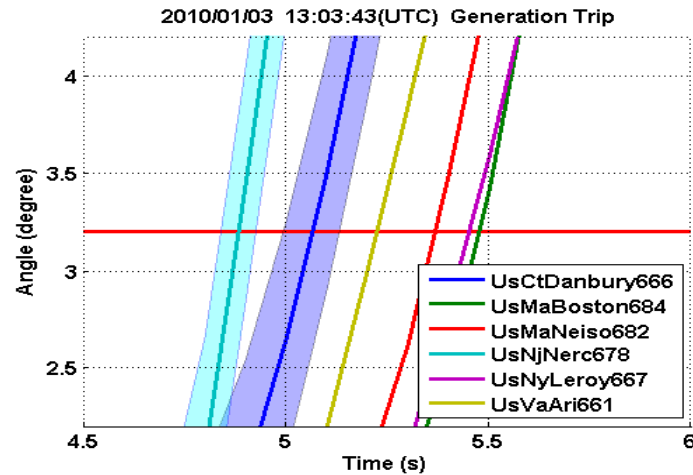
- An Example



$\pm 0.6^\circ$ error

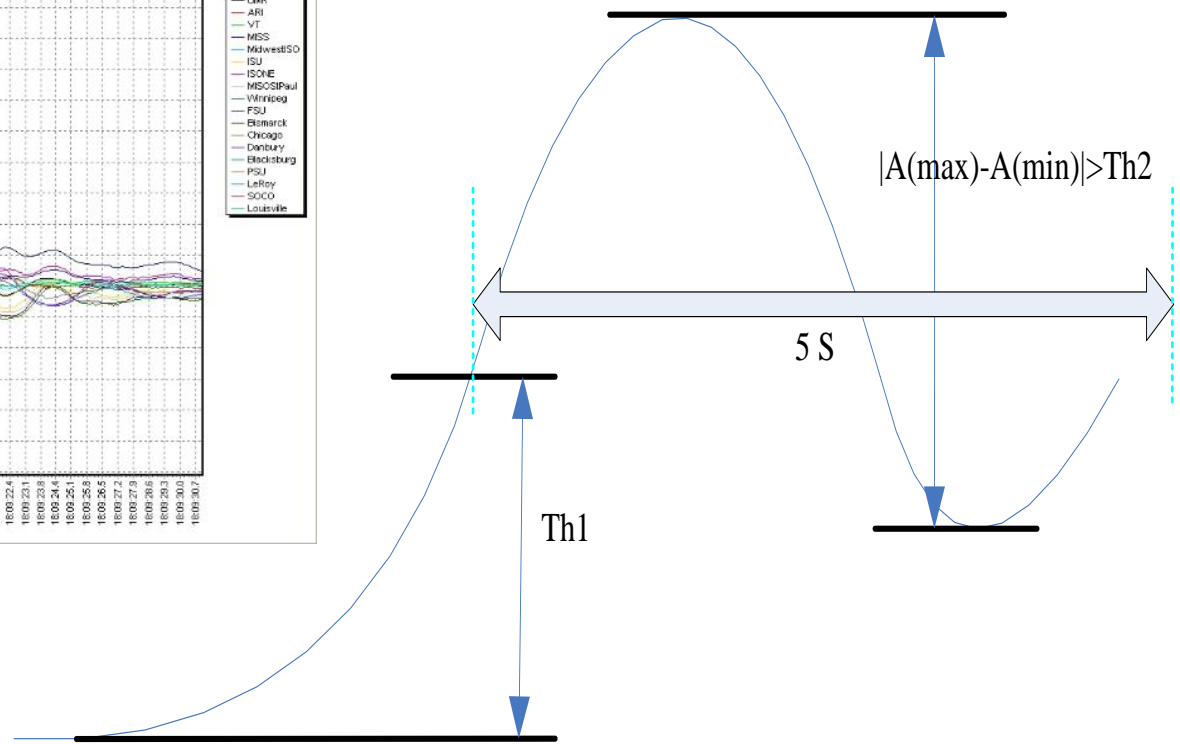
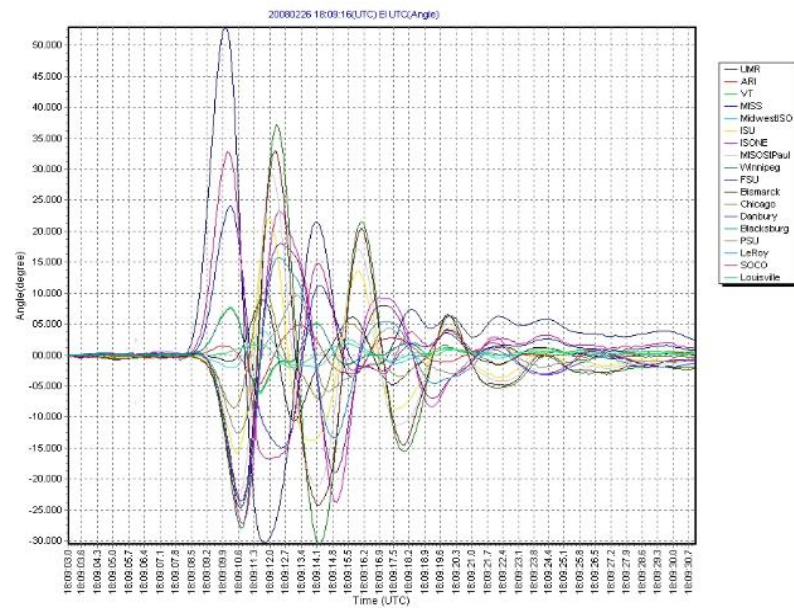


Most Scenarios Unaffected

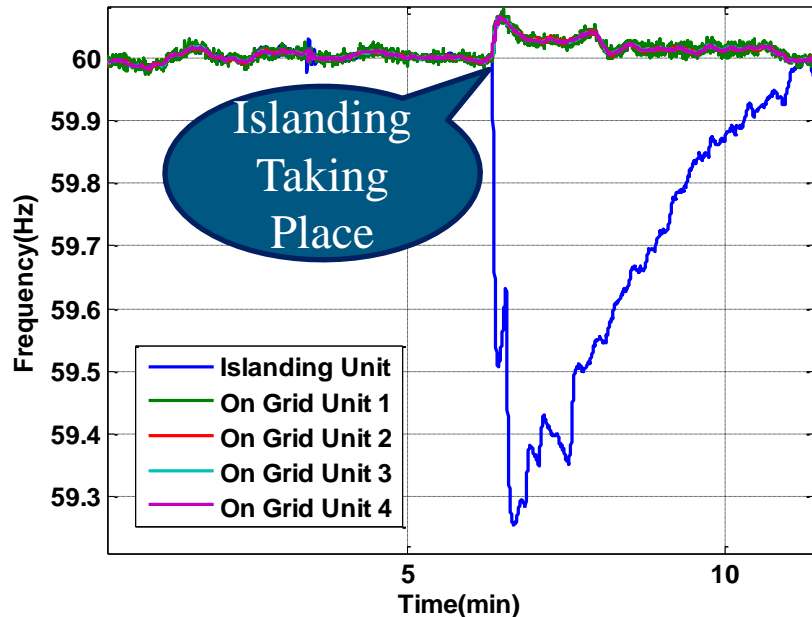


Oscillation Detection: Approach

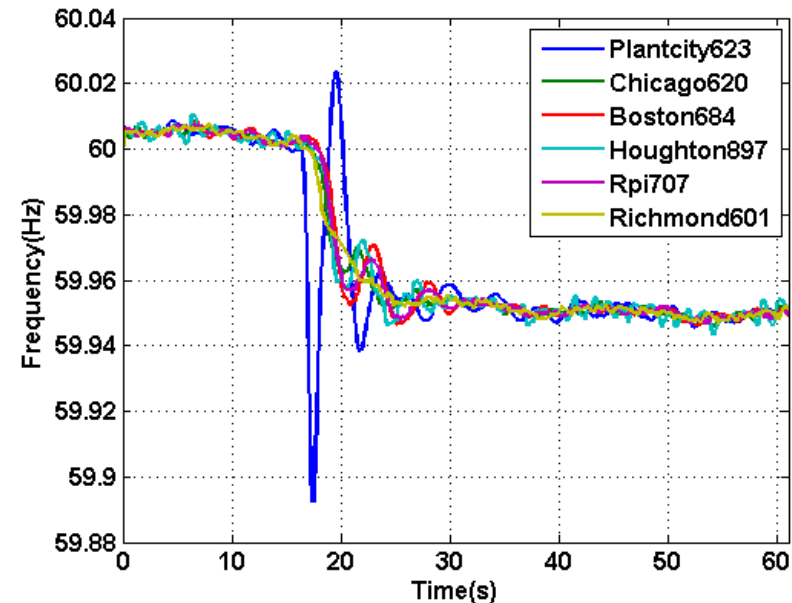
- Phase angle based two-threshold method



Islanding Detection: Frequency Based



Islanding



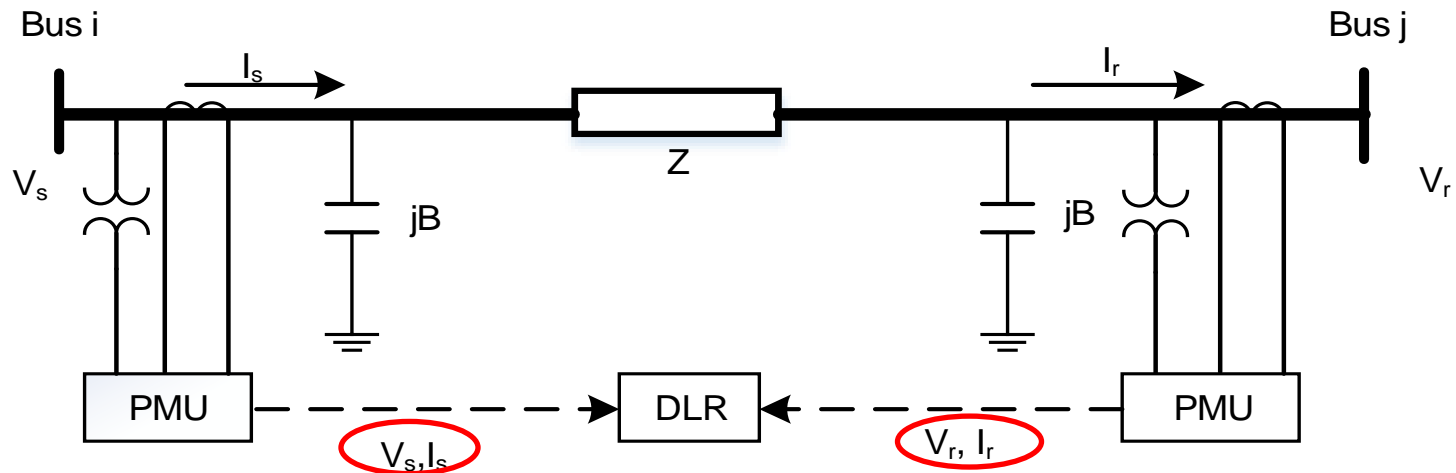
Generation Trip

Error may affect accuracy if < 1 second detection time is required at 30p/s rate. Time delay is required for false event rejection.



Dynamic Line Rating

- PMUs provide V and I phasors on both ends
- Consider only angle error in V and I
- Algorithm shown in references below

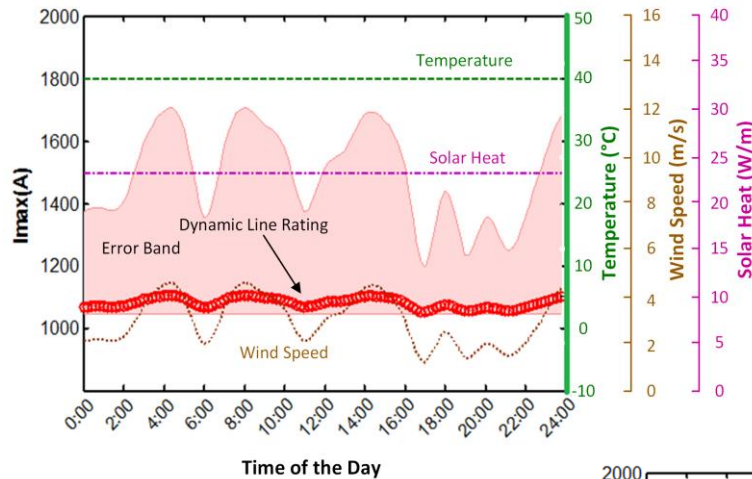


1. IEEE, "IEEE Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors", IEEE Std 738-1993
2. Sveinn Rúnar Júlíusson, "Using PMU Measurements to Assess Dynamic Line Rating of Transmission Lines", Aalborg University, 2013
3. J. Zhao, J. Tan, L. Wu, L. Zhan, et al., "Impact of Measurement Error on Synchrophasors Applications", Oak Ridge National Laboratory, 2015

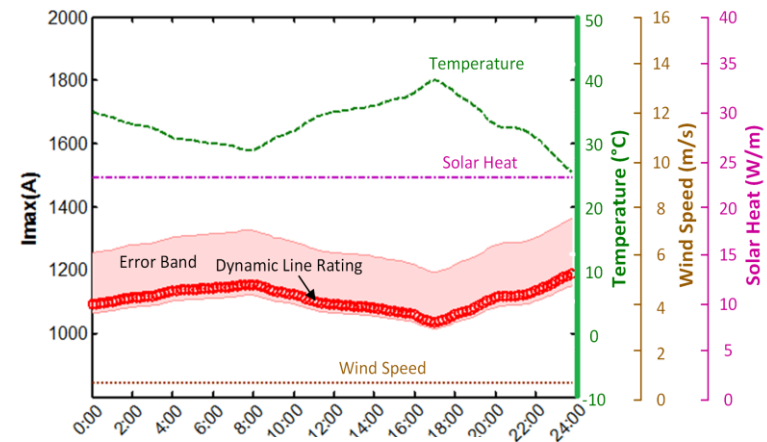


Influence of Different Factors

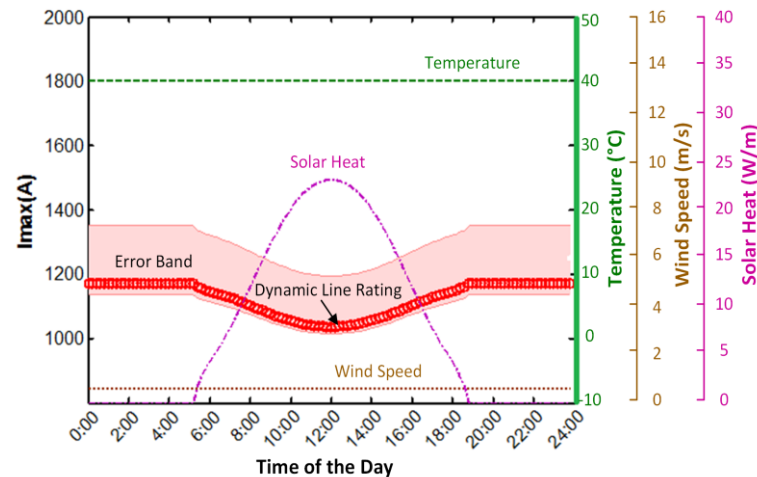
Wind Speed



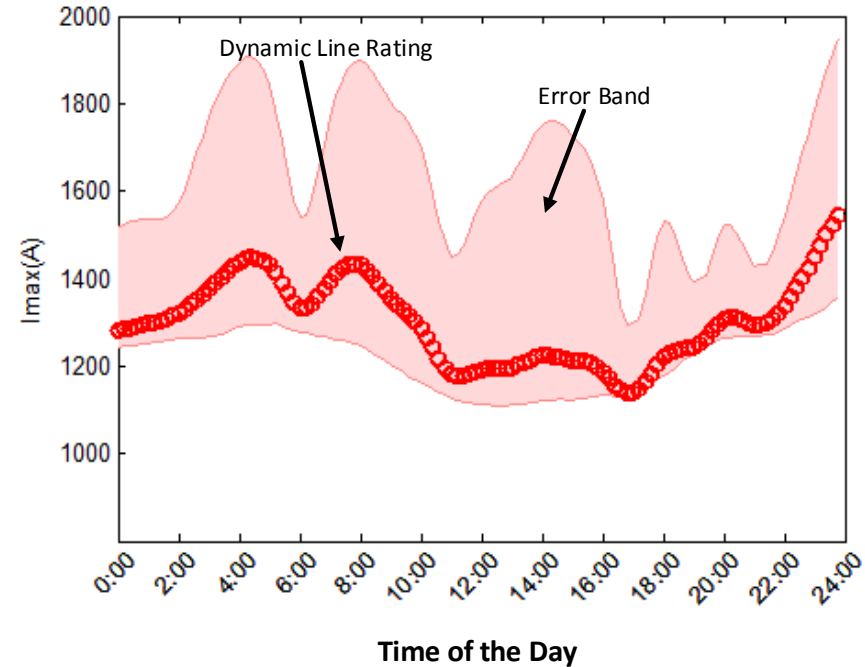
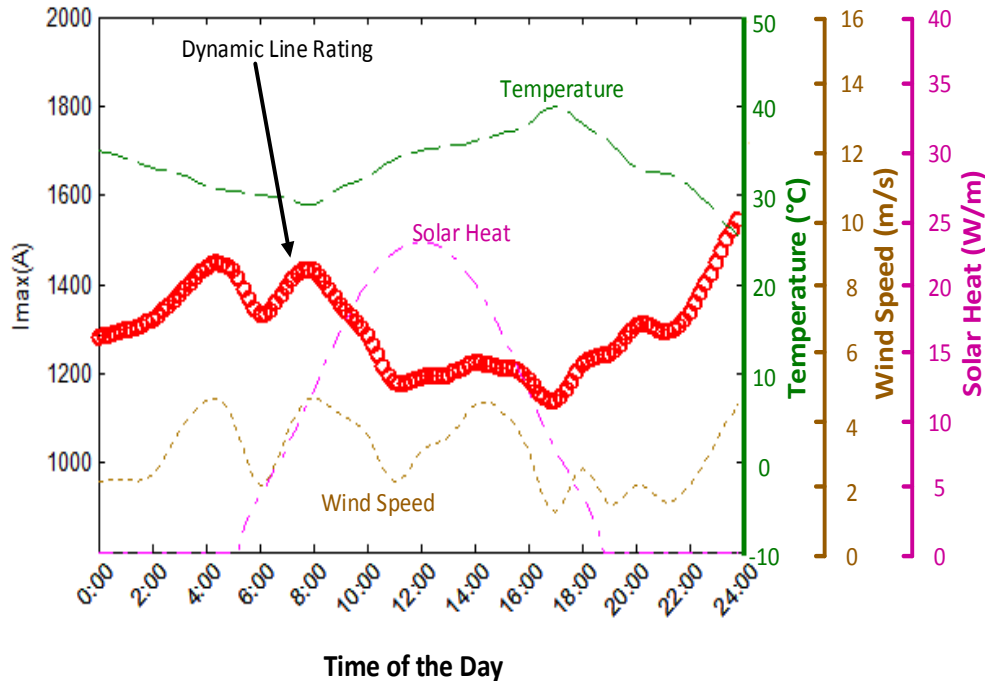
Ambient Temperature



Solar Heat



Error Impact



Summer
Errmax:45.87%



Conclusion

Application	Effect	Significance
Event location	A small number of cases show impact	Minor impact
Oscillation detection	Problem only for small magnitude cases	Threshold dependent
Islanding detection	Safe for detection time > 1 second	Detection time dependent
Dynamic line rating	Potential to introduce large errors	Very sensitive



Additional Information



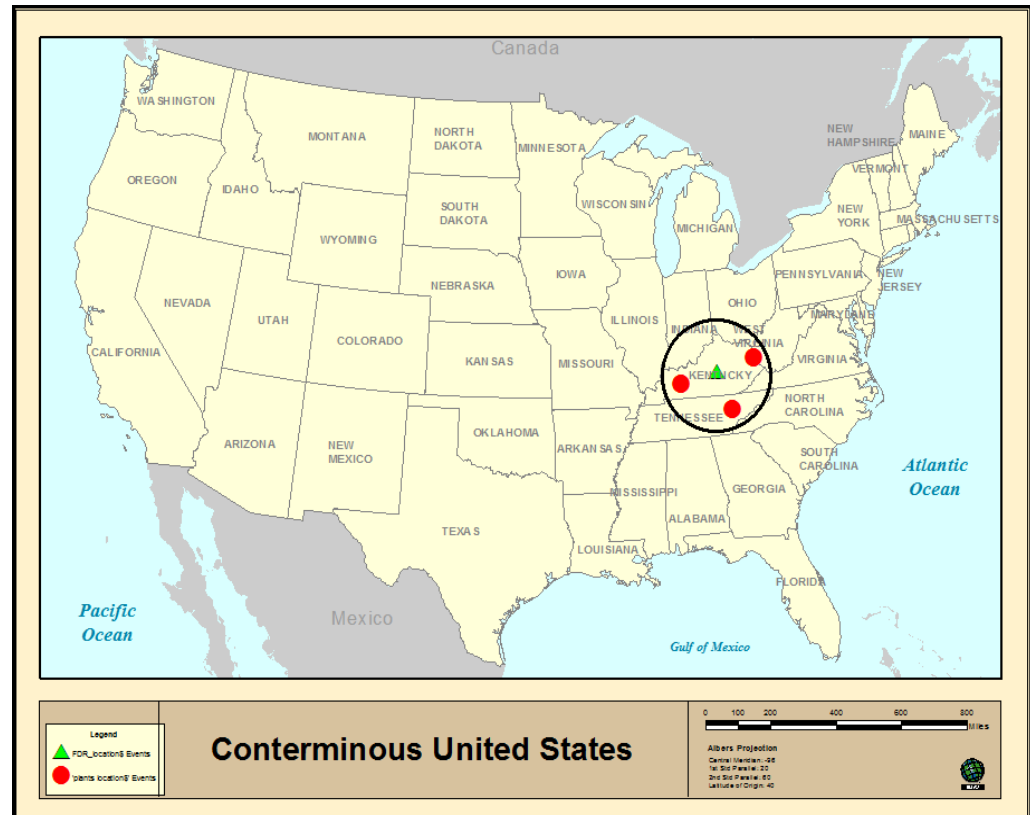
Event Location: A Brief Introduction

- Angle-Based Event Location

▲ : first responding FDR

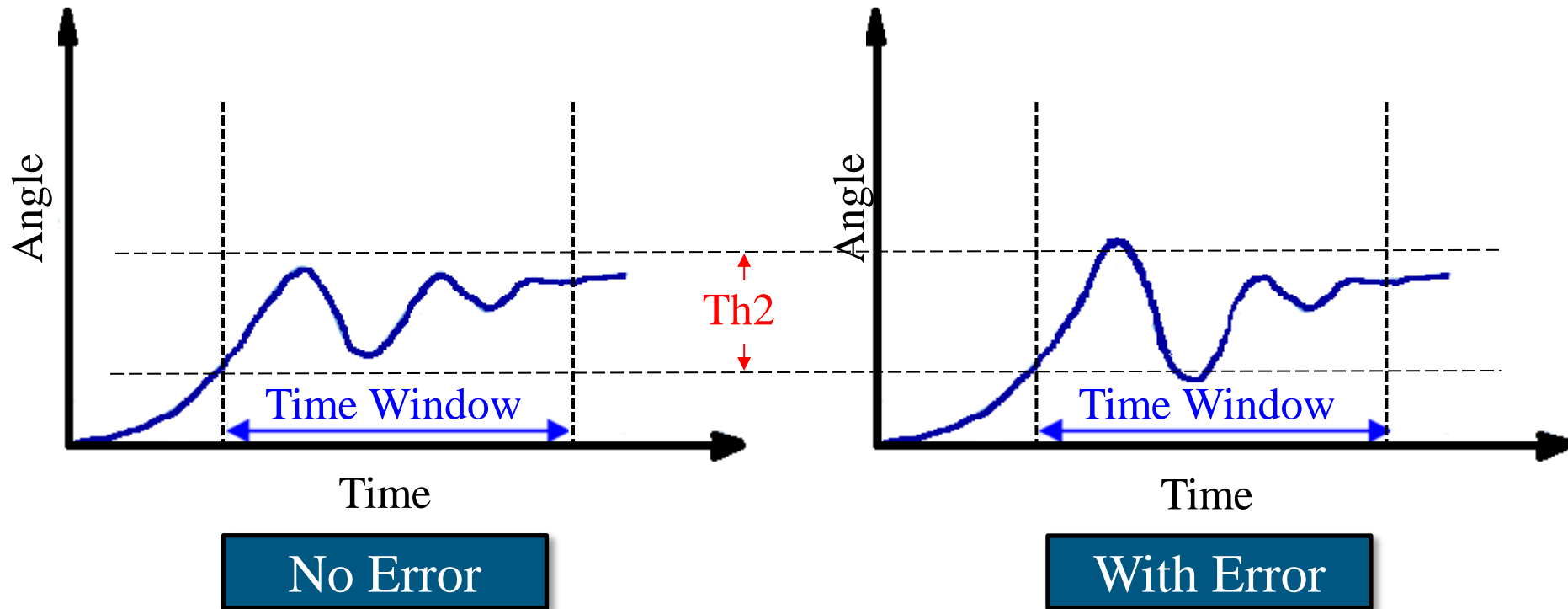
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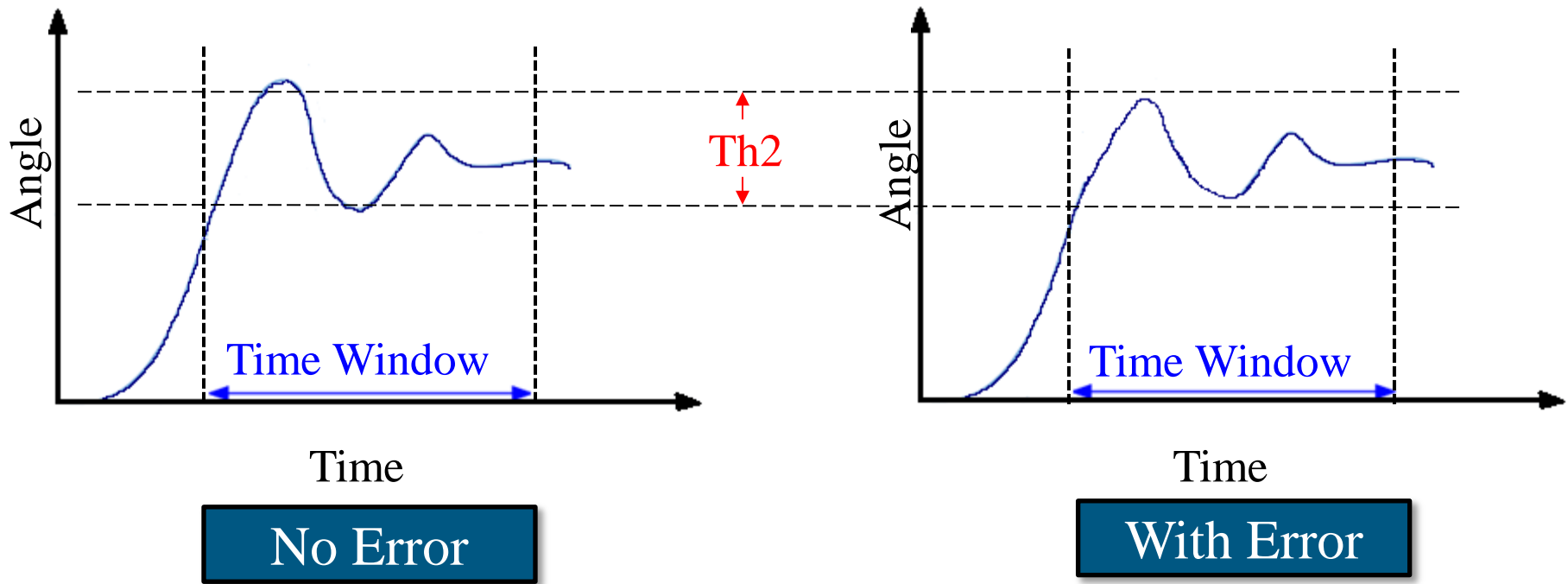
Impact of Error Depends on Thresholds

- False detection

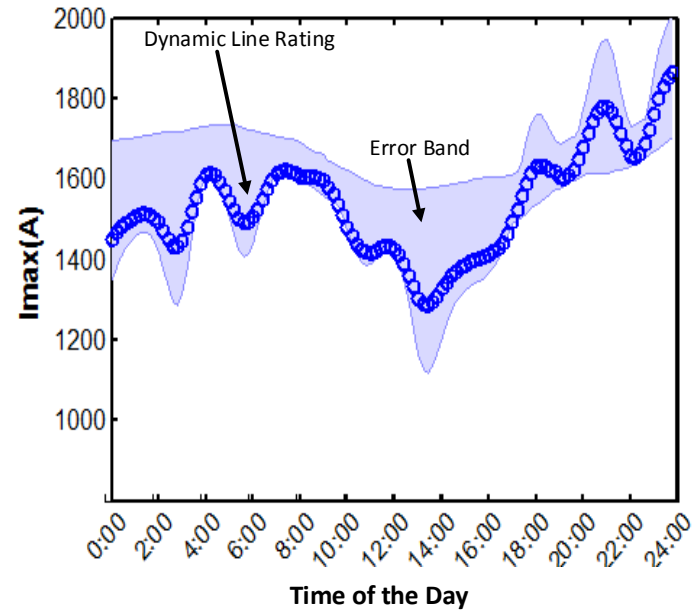
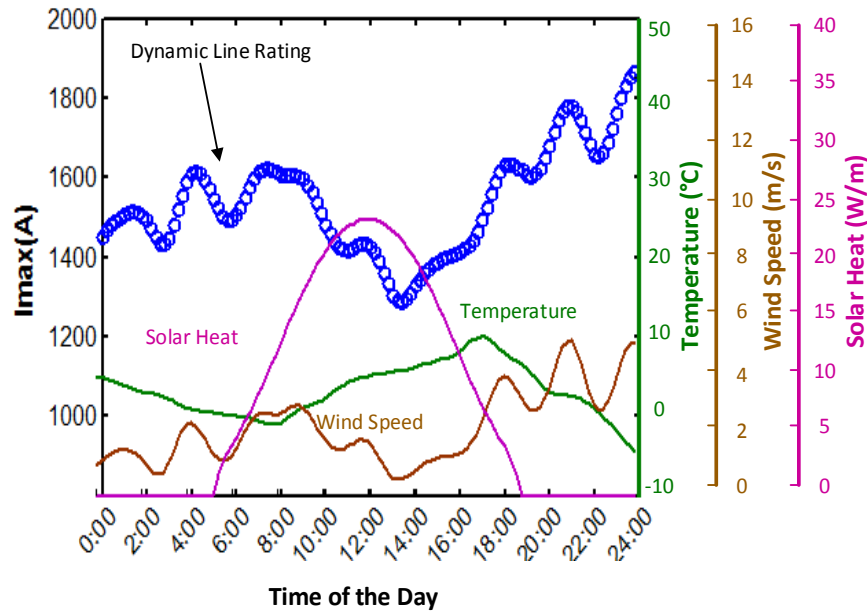


Impact of Error Depends on Thresholds

- Failed detection



Error Impact



Winter
Errmax:22.87%

